5»6G INNOVATION CENTRE
UNIVERSITY OF SURREY

GHz Bandwidth Sensing by Sub-Nyquist Signal Processing

Professor Yue Gao

University of Surrey

16 September 2021

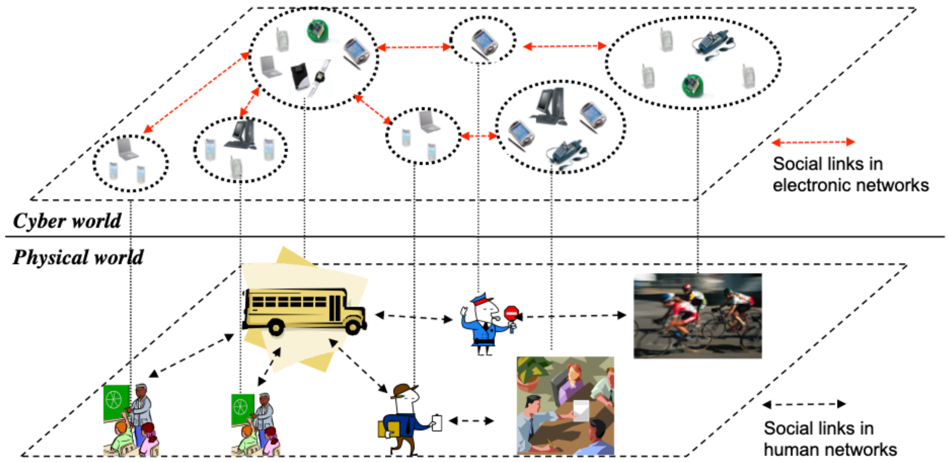
Contents

- Motivation and Background
- About the GBSense Project
- Sub-Nyquist Sampling Theory in a Nutshell
- Sparse Recovery Algorithms
- Wideband Spectrum Sensing Platform in Millimetre-Wave
- GBSense Prototype
- Conclusions and Future Plans

Thanks to

EPSRC Fellowship (2018-2023)

Cyber-Physical World Convergence



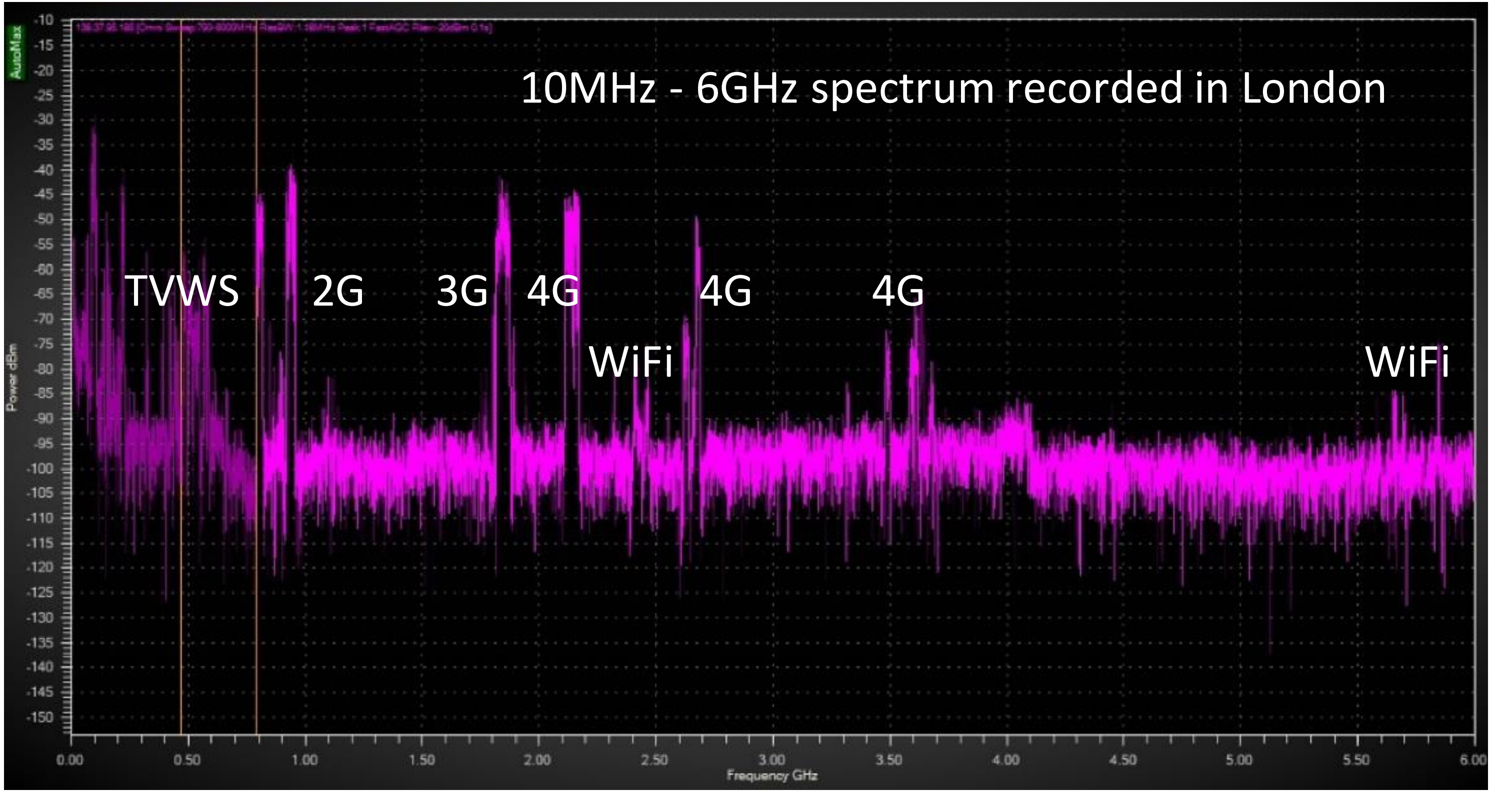
- Digitalisation -> **$100 trillion**
- Telecom - > **$2.1 trillion**
- **8 billion** devices connected to the internet now
- **1 trillion** devices by 2030

"The falling cost of advanced technologies is a defining characteristic of digital revolution. It is playing a major role in accelerating innovation."

Source: 2017 World Economic Forum Digital Transformation Initiative (DTI)

5»6G INNOVATION CENTRE
UNIVERSITY OF SURREY

Sensing spectrum availability at low financial and technical cost?



GBSense aims to dynamically access **unused** multi-GHz spectrum at **lower cost** for future wireless connectivity in both sub-6GHz and mm-wave frequency bands!

GHz Bandwidth Sensing System

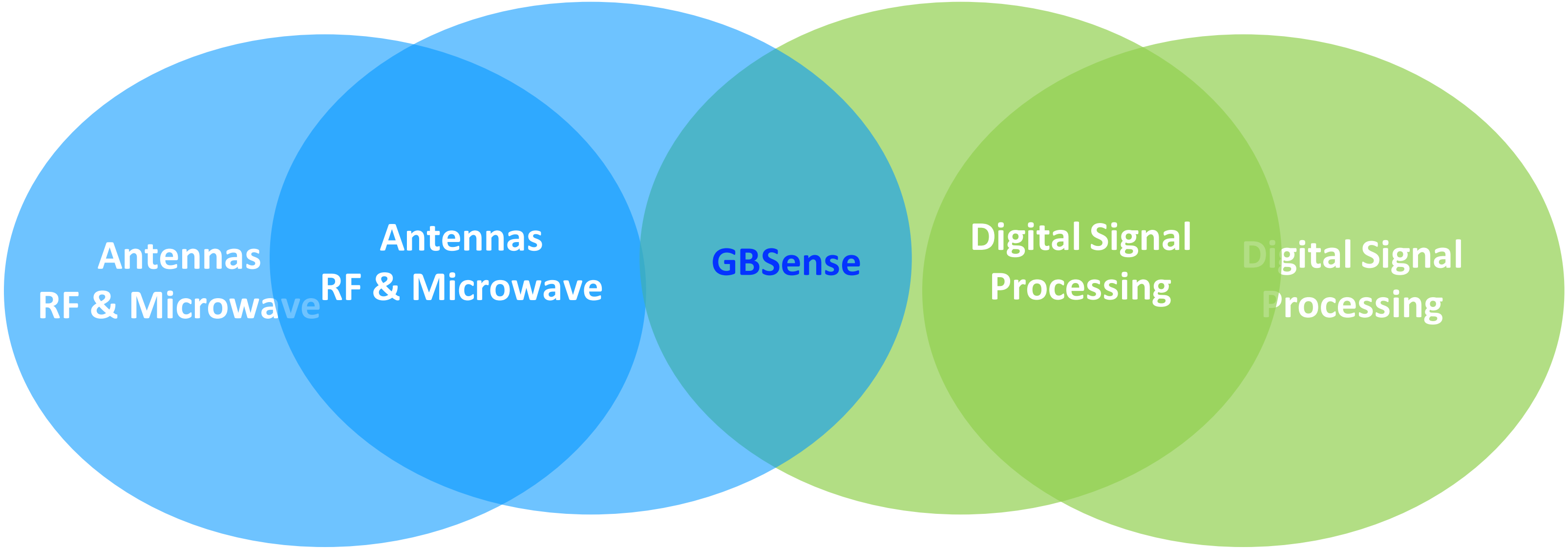
5»6G INNOVATION CENTRE
UNIVERSITY OF SURREY

Project website: www.gbsense.net

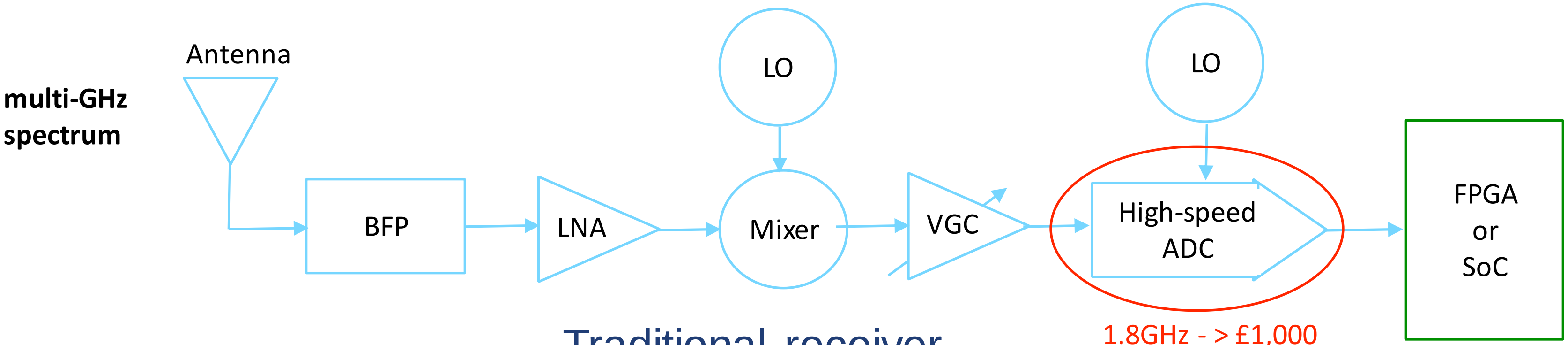
- Design GHz bandwidth sensing (GBSense) system to overcome the bottleneck of Nyquist-rate sampling by developing sub-Nyquist sampling algorithms.

- Provide users access to a flexible hardware platform and application software that enables real-time over-the-air GHz bandwidth signal sensing, analysis and communication at both sub-6GHz and mm-Wave frequency bands.

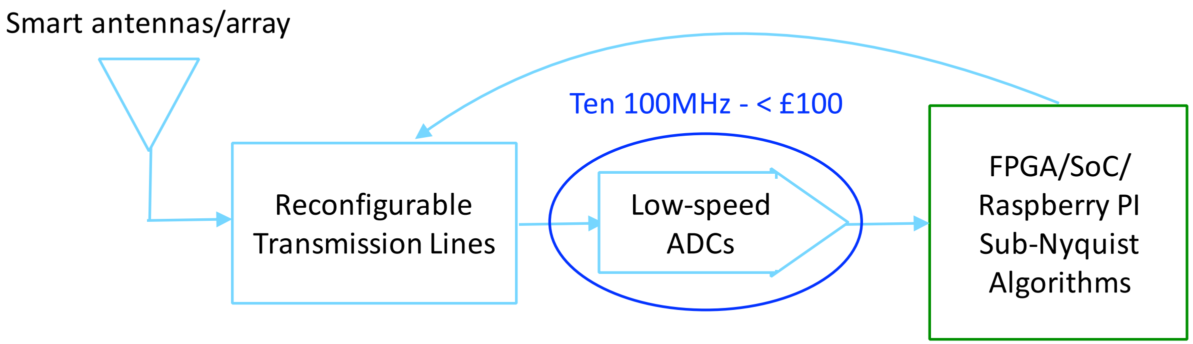
Co-creation between RF & Microwave and Signal Processing



GBSense receiver



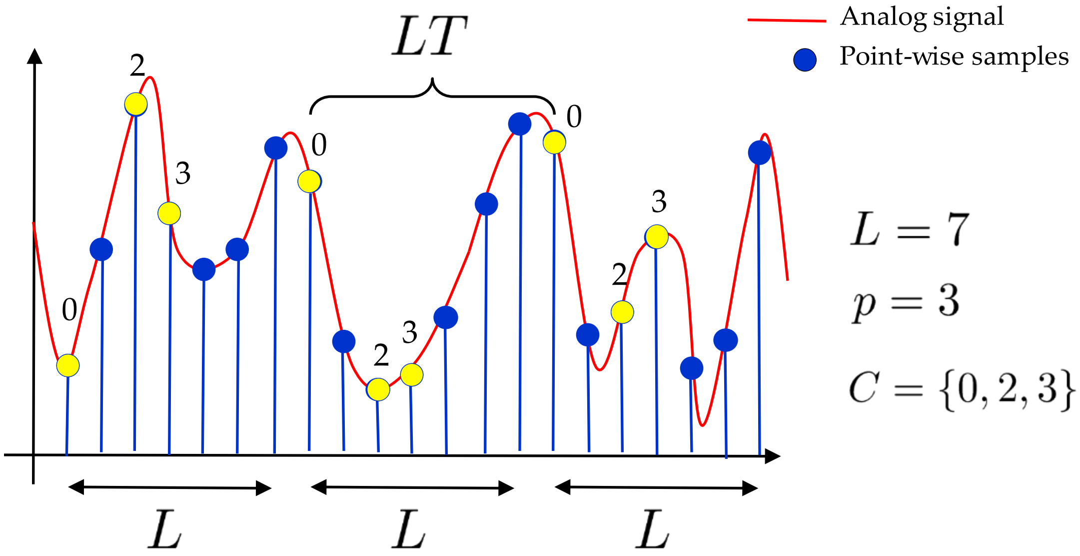
Traditional receiver



GBSense receiver

Sub-Nyquist Sampling Theory

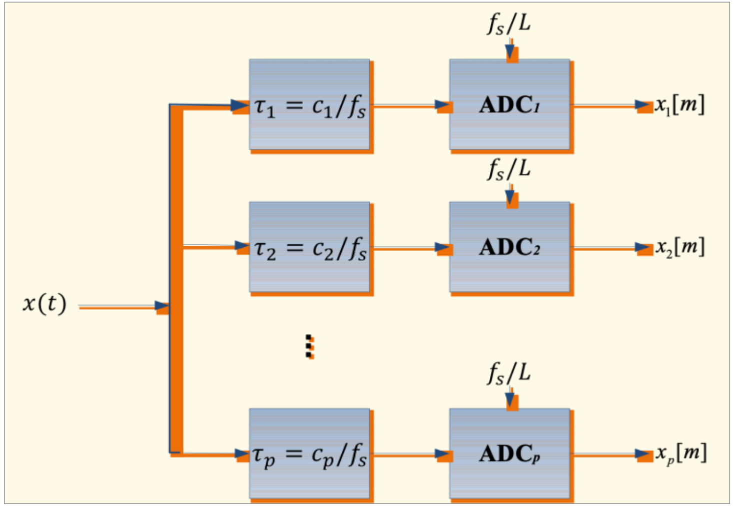
- Periodic Non-uniform sampling
- In each block of L samples, only p are kept, as described by $C = \{c_i\}_{i=1}^{p}$



$$L = 7$$

$$p = 3$$

$$C = \{0, 2, 3\}$$



Y. Ma, Y. Gao, Y. C. Liang, S. Cui, "Reliable and Efficient Sub-Nyquist Wideband Spectrum Sensing in Cooperative Cognitive Radio Networks," IEEE J. Sel. Areas Commun., vol. 34, no. 10, pp. 2750-2762, Oct. 2016.

Compressive Recovery Algorithms

Greedy Algorithms

Compared with Optimization Algorithms

Higher Computational efficiency

&

Higher reconstruction accuracy

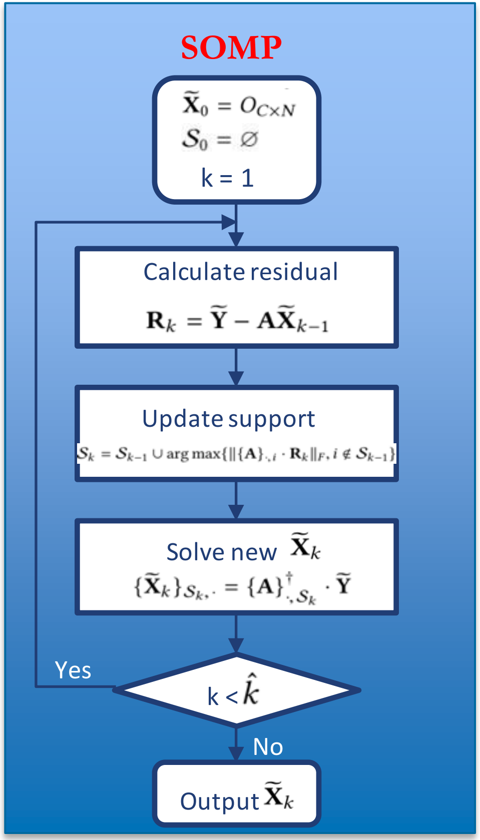
with prior knowledge

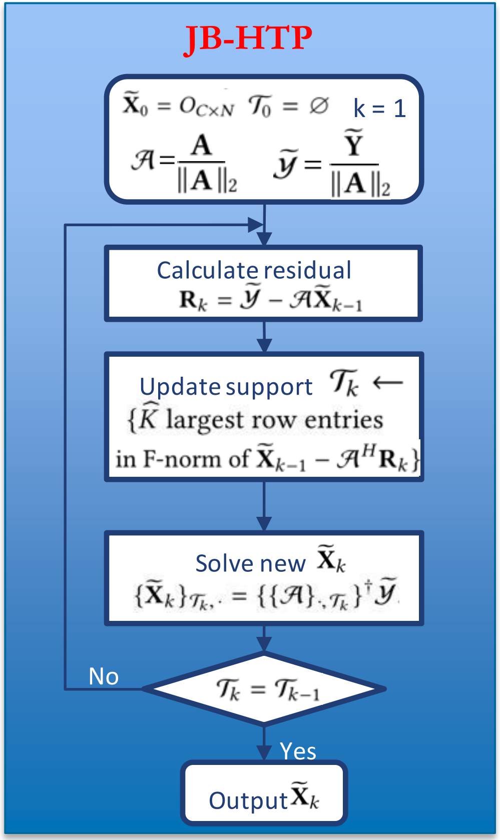
Simultaneous Orthogonal Matching Pursuit (SOMP):

Reconstruct sparse matrix row by row.

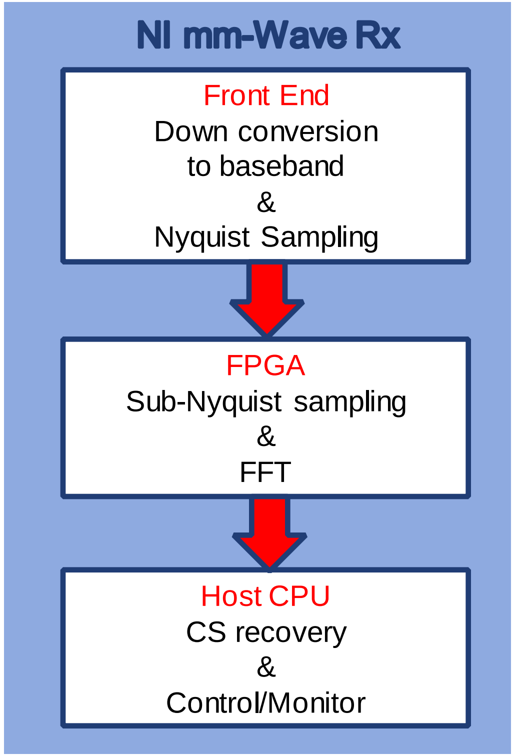
Joint-block-sparse Hard-thresholding Pursuit (JB-HTP):

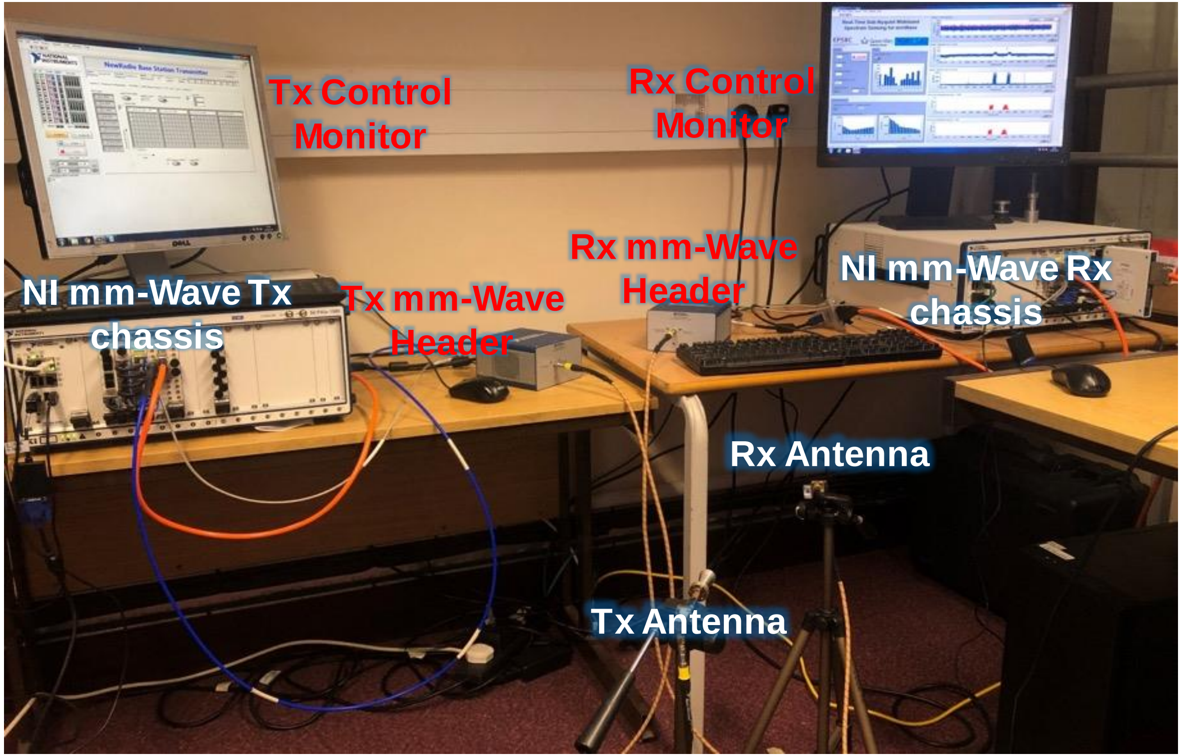
Reconstruct all possible non-zero rows together until the support converges.





Wideband Spectrum Sensing Platform in Millimetre-Wave



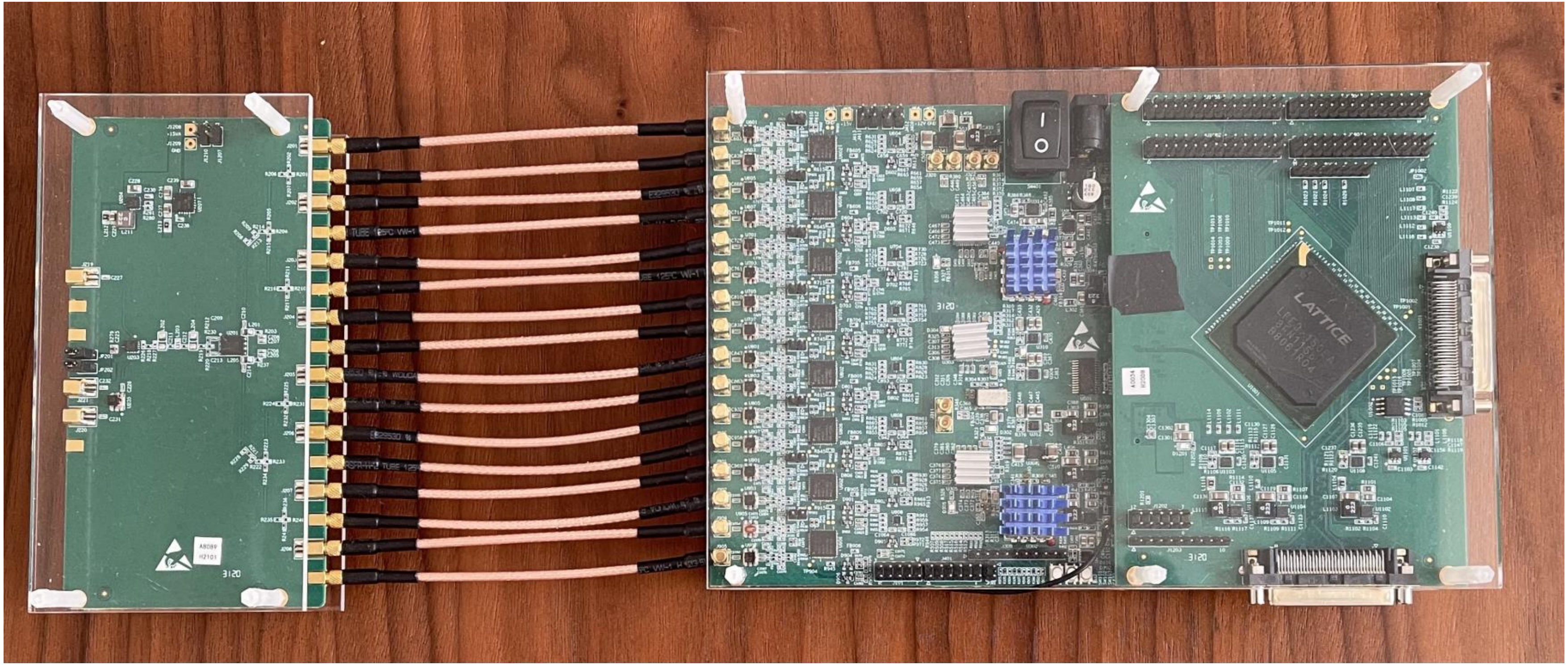


Z. Song, H. Qi, and Y. Gao, "Real-time multi-gigahertz sub-nyquist spectrum sensing system for mm-Wave," in Proceedings of the 3rd ACM Workshop on Millimeter-wave Networks and Sensing Systems, 2019, pp. 33–38. Click for more publications.

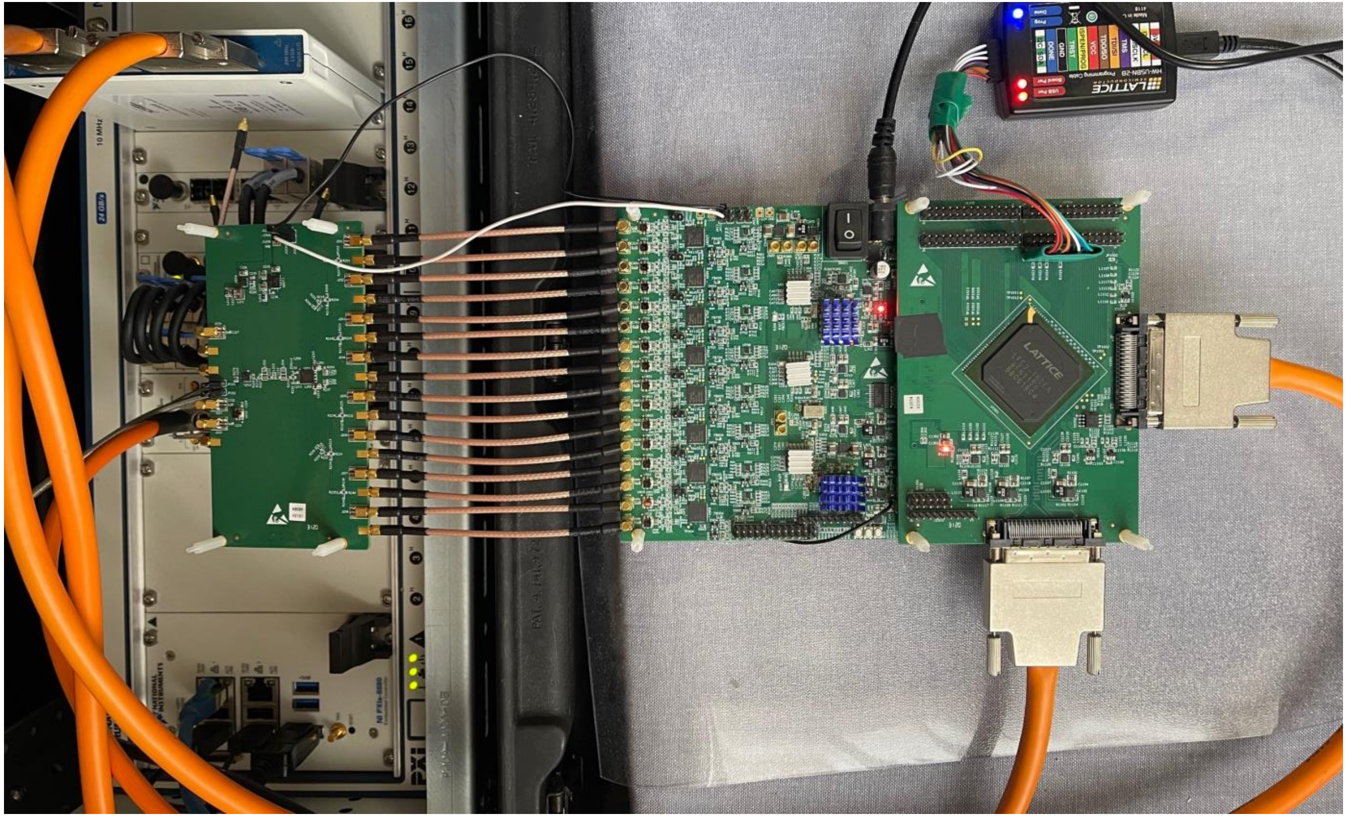
GBSense Real-time Software Demo at mm-Wave (NI LabVIEW)

- 5G FR2 @28GHz 100MHz channel BW
- Sub-Nyquist sampling with up to 3.072GHz and reconfigurable parameters
- Real-time spectrum sensing with up to 2GHz at 400MHz sampling rate
- Saving sampling by a factor of 5

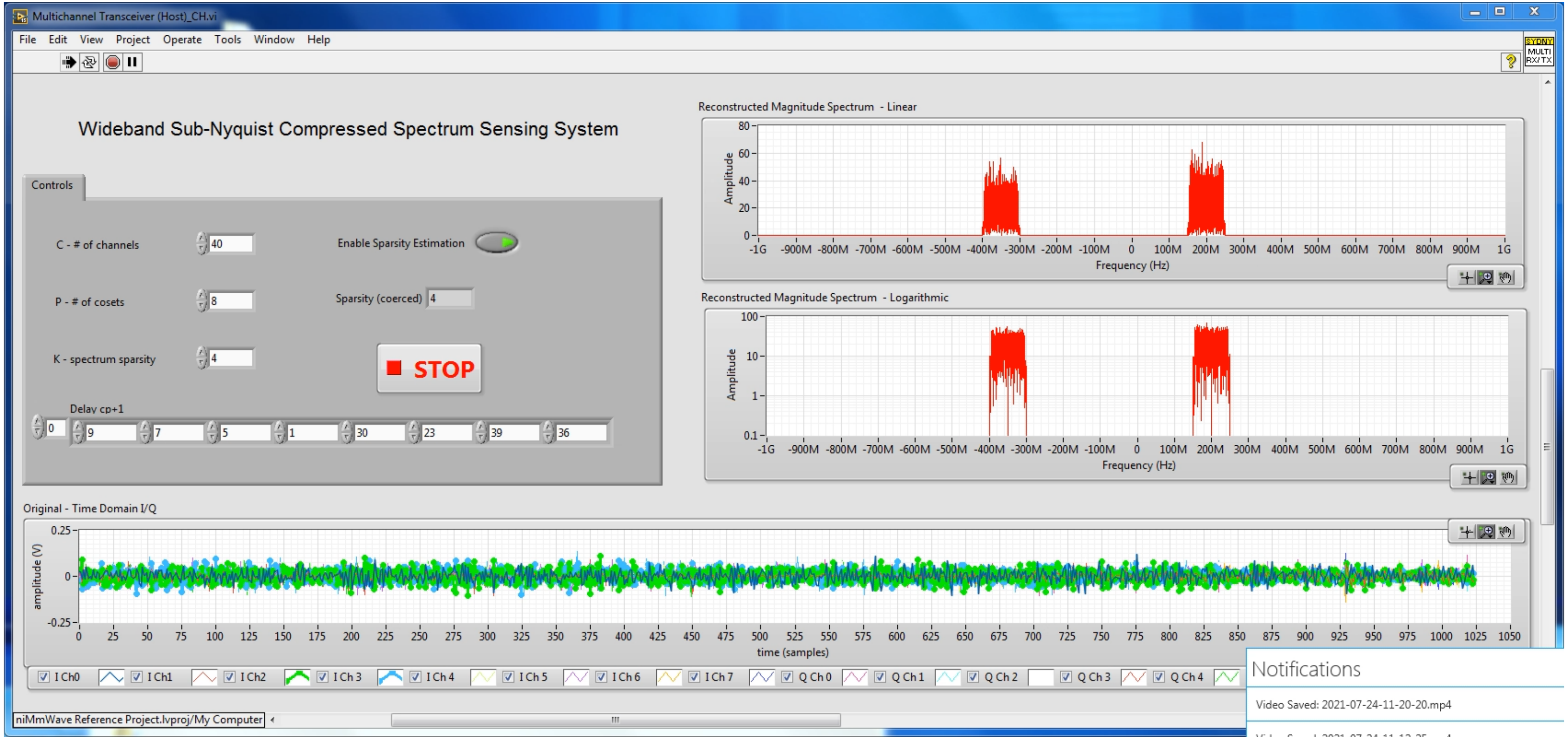
GBSense Prototype



GBSense Connecting to NI Millimetre-Wave Transceiver System



GBSense Recovery Algorithm on Hardware and Software Integration



Conclusions and Future Plans

Towards 5G+ and 6G

- Higher data rate requiring larger channel bandwidth
- Further hardware and software integration enabling smarter system design
- THz sensing and communications leading to high frequency bands

Future Plans

- Optimise sparse representation architecture
- Design new recovery algorithms via machine learning
- GBSense board connects to low cost computing units such as Raspberry PI

Thank You

Professor Yue Gao

yue.gao@surrey.ac.uk